

(19)



(11)

**EP 2 044 362 B2**

(12)

**NEW EUROPEAN PATENT SPECIFICATION**

After opposition procedure

(45) Date of publication and mention  
of the opposition decision:  
**26.09.2018 Bulletin 2018/39**

(45) Mention of the grant of the patent:  
**14.10.2015 Bulletin 2015/42**

(21) Application number: **07722638.9**

(22) Date of filing: **01.06.2007**

(51) Int Cl.:  
**F21K 99/00** <sup>(2016.01)</sup> **F21V 23/00** <sup>(2015.01)</sup>  
**F21V 29/507** <sup>(2015.01)</sup> **F21V 29/77** <sup>(2015.01)</sup>  
**F21Y 101/02** <sup>(2015.05)</sup> **F21V 23/04** <sup>(2006.01)</sup>

(86) International application number:  
**PCT/DK2007/000261**

(87) International publication number:  
**WO 2007/143991 (21.12.2007 Gazette 2007/51)**

(54) **A TUBULAR LED LIGHT SOURCE**

RÖHRENFÖRMIGE LED-LICHTQUELLE

SOURCE LUMINEUSE DE DEL TUBULAIRE

(84) Designated Contracting States:  
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR  
HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE  
SI SK TR**

(30) Priority: **12.06.2006 DK 200600790**

(43) Date of publication of application:  
**08.04.2009 Bulletin 2009/15**

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## Description

### Field of the invention

[0001] The invention relates to a new type of light source for replacement of fluorescent tubes. It is based on light emitting diodes (LEDs) and can be inserted in existing fittings for fluorescent tubes. Because of the LED technology and an intelligent embedded controller, the light source has a number of advantages compared to fluorescent tubes. Like other LED light sources the advantages for instance includes low energy consumption and markedly longer lifetime. The efficiency of the LEDs is highly dependent on the fact that their temperature is kept as low as possible. Therefore, the presented light source efficiently transfers the heat away from the LEDs. The embedded intelligent control also contributes to lowering the energy consumption of the light source, by constantly taking care that only the absolutely necessary amount of light is emitted.

### The state of art

[0002] There already exists a number patents describing LED based light sources for replacement of fluorescent tubes. Common to all of them is that they consist of a transparent tube, with the LEDs mounted inside. On the ends of the tube there are connectors so that it can be inserted into a fluorescent tube fitting. The following patents describe this configuration: US2005281030, US2003102810, US2004189218, US2004095078, CN1707153, and my own EP1618331. They all have the LEDs mounted along the whole length of the tube and in all directions, so that light is emitted all around the tube in an omnidirectional pattern.

[0003] Other patents like WO2005017966 and US2004156199 have the LED's mounted in the ends of the tube, projecting the light against the middle of the tube. By using optics the light is then distributed all over the tube.

[0004] US2002060526 and US2005225979 only emit light from a limited part of the surface of the tube. It is done by using reflectors or by just having the LEDs pointing in the desired direction.

[0005] An example of an LED light source not directly targeted against replacing fluorescent tubes is US2002125839. It considers the thermodynamics a bit more, since heat sinks are mounted on the backside of the LEDs. However, both the LEDs and the cooling fins are still encapsulated inside a transparent tube. WO 03/103064 A1 discloses a light source according to the preamble of claim 1.

[0006] Concerning an embedded controller, the light source described in patent US2005281030, has embedded sensors for detection of daylight level and a movement-sensor for detection of persons. The sensors communicate with an embedded computer which can control the illumination level. The computer can also communi-

cate with other light sources of same type or with a PLC (Programmable Logic Controller). All communication can be implemented by an extra special cable or wireless.

[0007] Concerning control of the color temperature of the light, there already exists a number of LED light sources with this feature. They function by mixing the light from red, green and blue (RGB) LEDs. The following patents describe such light sources: TW226791B, WO2005030903, US2005157515, DE102004002398, and CN1619810. None of them relate to replacement of fluorescent tubes.

### The advantages of the present invention compared to state of art

[0008] All of the known LED based light sources for replacement of fluorescent tubes, are constructed to look like a fluorescent tube as much as possible, it is not necessary. They are encapsulated inside a transparent tube which, beside of the cosmetic effect, actually only serves as protection of the electronics inside the tube. The solution with a transparent tube has some very essential disadvantages. The tube works like a greenhouse, where the LEDs and the electronics inside the tube have no chance to get rid of the heat. The heat is accumulated and the efficiency of the LEDs decreases proportional to the time the light source has been turned on. Another disadvantage with the transparent tube is that a part of the emitted light is absorbed in the tube. Thereby light is lost and the total efficiency of the light source is decreased even more.

[0009] The present invention does not have the stated disadvantages. Here the LEDs are mounted on the outside surface of the heat conducting tube. Thereby, the heat from them is distributed all over the surface of the tube, and the tube allows heat diversion to the surroundings. The heat conducting tube is in direct contact with the ambient air of the light source, where to the heat is easily transferred. The control electronics are mounted inside the tube, thermically connected to the tube, whereby the heat from the said electronics can efficiently be transferred to the tube. Because of the LEDs being mounted on the outside of the tube, the light is emitted directly to the surroundings and has unimpeded access to the surroundings. The LEDs are still sufficiently protected since the electrical connections are enclosed in an electrically isolating material, which is also thermically conducting.

[0010] The existing light source (US2005281030) with a kind of intelligent embedded control, which is also based on a transparent tube, has embedded light sensors only for detection of the light level. The light sensors in the present invention, detect the whole spectrum of the light in the surroundings. This means that not only the illumination level but the overall light quality in the surroundings can be detected. Light quality is defined as color temperature and illumination level.

[0011] In the patent US2005281030, communication

between light sources and/or a central PLC, is mentioned. The communication can be implemented by a special separate cable or wireless. None of these methods are optimal in this application. Wireless communication uses relatively much energy, not just when it is used but also in the standby mode, to be ready for communication. This is not optimal in an application targeted for energy savings. To introduce an extra cable, which shall connect each fitting/tube in an illumination system, increases the cost of the application even more. It also makes it more difficult to install. Therefore, this is not a good solution. The present invention solves the communication problem by using the existing installed power cable as a communication line. Modulated signals, which do not disturb the power line, are then transmitted over the cable. Further, this solution requires no new installations and the energy consumptions is kept at a minimum.

**[0012]** The color temperature, which is one of the major disadvantages of the traditional fluorescent tube, and one of the reasons why the incandescent bulb is still on the market, has not been improved in the known LED based light sources for replacement of fluorescent tubes, even though the LED technology makes light in any color or color temperature possible. Also the color temperature of the incandescent bulb. The present invention makes benefit of this. It can be configured to any color temperature.

#### The new technical means and effects

**[0013]** The present invention is based on a tube (1) manufactured in a heat conducting material, where the LEDs (2) are mounted on the outside of the tube. The LEDs are evenly distributed on a minor part of the outer surface on the tube. The rest of the outer surface (6) is used for diversion of the heat (15) to the surroundings. The control electronics (7) are placed inside the tube, electrically connected with the connectors (10) on the ends of the tube and the LEDs (2) and the sensors (12 and 13) on the outside of the tube. The control electronics: (7) are thermally connected to the tube (1). The effect is that the heat from the LEDs is efficiently moved away. Thereby, their temperature is kept minimal, and their efficiency is increased significantly. In addition, there is no unnecessary loss of light, since the light is not transmitted through a transparent tube, but is instead directly transmitted to the surroundings. A typical transparent acrylic tube absorbs about 10 percent of the light.

**[0014]** The invention described herein has connectors (10) on both ends of the tube, dimensioned so that they fit into the sockets of an existing fluorescent tube fitting. The effect is that the invention can be a direct replacement for fluorescent tubes.

**[0015]** The end pieces (9) at the ends of the tube, where the connectors (10) are located, seal the tube tight. The connections (4) from the control electronics (7) inside the tube to the LEDs (2) on the outside, are also sealed. Inside the tube all air is sucked out so that there is a

vacuum (20). The effect is that the electronics inside the tube are protected against condensed water and the damages this may generate. Thereby, the light source is also able to function in very cold surroundings.

**[0016]** The control electronics (7) can log all information concerning the operation of the light source. As examples: when and how the light is turned on/off or adjusted, or when the sensors detect a person in the room. The information can be stored in a database. The control electronics can extract statistics from the database/log, and thereby analyze the usage patterns. The purpose of this is an overall minimization of the light usage.

**[0017]** The embedded control electronics can communicate with other light sources of the same type, or a central control unit, on the same illumination system. The communication takes place on the existing installed power cable, which already connects all the fittings in the illumination system. This communication does not disturb the power line, since it operates in another frequency band, and has a much lower amplitude. The communication can as an example be implemented by DTMF-modulation, which is used in telephone networks to transmit numbers. Another more advanced method for communication could be Powerline Networking, which in principle is Ethernet transmitted over the power line. Both technologies are already highly developed standards. The effect is that the light sources in an illumination system, which originally were controlled by a central switch, now become individual light sources capable of being turned on/off and adjust their light output individually. The commands can be sent by the light sources or by a central control unit. This increases the flexibility and the opportunity of energy savings significantly. As an example, a warehouse, where there in principle only needs to be light where the fork lift trucks work, would benefit from the present invention. The present invention makes it possible only to have light at these locations. The fork lift trucks can be detected by the embedded sensors of the light sources. By communicating with the adjacent light sources, the light sources can generate an illuminated area around the fork lift trucks. Thereby a lot of illumination and energy can be saved. The LEDs in the present invention can be turned on/off or adjusted immediately, without any problems or damage to the light source.

**[0018]** The present invention has one or more embedded sensors (12) for detection of the light quality in the surroundings. The sensors measure the contribution of light from daylight or other artificial light sources. Detection of light quality means detection of the whole spectrum in the visible light band. From this not only the light level, but also the color temperature can be derived. The sensors communicate with the embedded control electronics. The effect is that the light source is capable of adjusting the total light level in its surroundings. Thereby, the light source only uses the exact amount of energy needed to keep up the required light quality in the surroundings.

**[0019]** The present invention has embedded move-

ment sensors (13). They might be of the well known type PIR (Passive Infrared). They can detect warm objects such as persons or vehicles in the illumination area of the light source. The sensors communicate with the embedded control electronics. The effect is, as earlier mentioned, that the light source can be turned on when it is needed, and turned off when not.

**[0020]** Instead of using normal LEDs in the present invention, a special kind of LEDs called organic light emitting diodes (OLED) can be used. The effect is a more homogeneous illumination and a more compact design, and may be in the future a more attractive light source.

**[0021]** The embedded control electronics (7) have a functionality to adjust the light level, either general or specific for each of the color components Red, Green and Blue (RGB). The effect is that light in any color temperature or colors can be emitted.

**[0022]** The LEDs (2) which are mounted on the outside of the tube may consist of different groups. Each group represents a direction of illumination. Each group can be controlled individually. The effect is that the illumination direction of the light source becomes dynamic and can be changed electronically. This gives an opportunity for further energy savings and decorative effects. As an example, a lecture room with large windows with a lot of daylight input can benefit from the present invention. As the day progresses and the daylight changes angle and strength, the light source can compensate for this by changing the illumination direction and light level.

**[0023]** Thereby, the black boards and the desks always receive the required amount of illumination.

Drawing

**[0024]**

Fig. 1 shows a cross section of the light source

Fig. 2 shows the light source as seen from the end

Fig. 3 shows the light source as seen from the side

Fig. 4 shows an alternative design of the light source

Fig. 5 shows another alternative design of the light source

#### Preferred embodiment of the invention

**[0025]** The present light source can be based on an specially extruded aluminum tube (1). It is shaped so that the one half side, has a surface like a regular polygon, with 6 edges (see Fig.1). On the other half side, the surface area consists of cooling fins (6), to maximize the convection of heat (15). On each edge of the polygon SMD LEDs (2) are mounted, emitting light (14) in directions perpendicular to the edges of the polygon. The terminals of the SMD LEDs are connected electrically to thin printed circuit boards (PCB) (3), taking care of electrical connections between each LED. The back side of the LEDs are thermally connected to the aluminum tube. To protect and isolate the electrical connections on

the outside of the tube, the terminals of the SMD LEDs and the PCBs are potted into a heat conducting epoxy compound (5). The PCBs on the outside of the tube are connected by wires (4) to the embedded control electronics (7) inside the tube. The wires go through holes in the tube, which are also sealed with an epoxy compound. On the inside of the tube there are two grooves (23), where the PCB containing the control electronics (7) is to be mounted. The heat generating components (8) of the control electronics are thermally connected to the aluminum tube. In each end of the tube there is a tight-fitting end piece (9), with connectors (10), dimensioned so that they fit into a fluorescent tube fitting. The profile of the cooling fins on the tube, continues to the end pieces (11). This is done to improve the air stream along the cooling fins, especially when the tube is mounted in a vertical fitting. Inside the tube there is vacuum (20) in order to avoid condensed water, which could damage the control electronics. Along the tube the LEDs are evenly distributed, to make the illumination homogenous (see Fig. 2). The sensors for detection of movement (13) and spectrum distribution of the light (12) are placed outside the tube and are also connected to the control electronics inside the tube.

#### A second exemplary embodiment

**[0026]** The design of the light source according to a second exemplary embodiment, which is not part of the invention, is shown on Fig. 4. The aluminum tube (1) is still shaped like a regular polygon on one half side. The number of edges depends on the requested angle of illumination of the light source, as well as the radiation pattern of the LEDs. In this case 3 edges are enough. On the other half side of the tube, the surface is curved (16). This will give enough surface area to cool down the tube, as the LEDs becomes more efficient by time. Thereby the curved surface functions as the heat sink. On each edge of the polygon-side there are still LEDs evenly distributed. This time not as SMD-components, but as raw LED-chips (17) in order to minimize the cost, the LED-chip is thermally connected to the aluminum tube and electrically bonded directly to the PCB (3) by thin wires (21). It is all sealed into a transparent heat conducting epoxy compound (19). Inside the tube the control electronics (7) are distributed on a number of stacked PCBs. The PCBs are kept in place by some rails (18) inside the tube. The rest of the implementation of the light source is identical with the one mentioned in the first embodiment.

#### A third exemplary embodiment

**[0027]** Fig. 5 shows a third exemplary embodiment which is not part of the invention. The difference between this and the earlier mentioned embodiments, is that instead of using a number of discrete LEDs, uses one module (24) consisting of a number of organic light emitting

diodes (OLED).

#### Claims

1. A tubular light emitting diode (LED) light source, comprising:

a tube (1) manufactured in a heat conducting material and having an interior and an outside surface, the tube (1) being in direct contact with the ambient air of the light source; and a plurality of LEDs (2) mounted and evenly distributed on a part of the outside surface of the tube (1); **characterized by:**

control electronics (7) disposed inside the tube (1) and electrically connected to the LEDs (2);

connectors (10) located at opposite ends of the light source, wherein the connectors are dimensioned to fit into sockets for fluorescent tubes, and wherein the connectors (10) are electrically connected to the control electronics (7); and wherein on one half side of the outside surface area of the tube (1) the tube consists of a plurality of cooling fins (6).

2. A tubular LED light source according to claim 1, **characterized in that** there is a vacuum (20) inside the tube (1).
3. A tubular LED light source according to claim 1, **characterized in that** the control electronics (7) can store information about the operation of the light source, and analyze the information to minimize the energy consumption.
4. A tubular LED light source according to claim 1, **characterized in that** the control electronics (7) can communicate, with other light sources or a central control unit, by the existing installed electric power cable.
5. A tubular LED light source according to claim 1, **characterized by** having one or more embedded sensors (12) to measure the spectrum of the light from the surroundings.
6. A tubular LED light source according to in claim 1, **characterized by** having one or more embedded sensors (13) to measure movements in the surroundings of the light source.
7. A tubular LED light source according to claim 1, **characterized in that** on the outside surface of the tube (1), one or more organic light emitting diodes (OLED) (24) are mounted.

8. A tubular LED light source according to claim 1, **characterized in that** the color components, in the emitted light, can be adjusted individually.

9. A tubular LED light source according to claim 8, **characterized in that** the color components are red, green and blue.

10. A tubular LED light source according to claim 1, **characterized in that** the illumination area of the light source can be adjusted, by turning on/off or dimming some of the LEDs (2).

11. A tubular LED light source according to any of claims 1-10, wherein the tube is an extruded aluminum tube.

#### Patentansprüche

1. Rohrförmige Leuchtdioden(LED)-Lichtquelle mit einer Röhre (1), die aus einem wärmeleitenden Material gebildet ist und eine Innenfläche und eine Außenfläche aufweist, wobei sich die Röhre (1) in direktem Kontakt mit der Umgebungsluft der Lichtquelle befindet; und einer Mehrzahl von LEDs (2), die auf einem Teil der Außenfläche der Röhre (1) montiert und gleichmäßig verteilt sind; **gekennzeichnet durch** eine Steuerelektronik (7), die innerhalb der Röhre (1) angeordnet ist und elektrisch mit den LEDs (2) verbunden ist; Anschlüsse (10), die an entgegengesetzten Enden der Lichtquelle angeordnet sind, wobei die Anschlüsse so dimensioniert sind, dass sie in Fassungen für Fluoreszenzröhren passen, und wobei die Anschlüsse (10) mit der Steuerelektronik (7) elektrisch verbunden sind; und wobei auf einer halben Seite des Außenflächenbereichs der Röhre (1) die Röhre aus einer Mehrzahl von Kühlrippen (6) besteht.
2. Rohrförmige LED-Lichtquelle nach Anspruch 1, **dadurch gekennzeichnet, dass** ein Vakuum (20) innerhalb der Röhre (1) vorliegt.
3. Rohrförmige LED-Lichtquelle nach Anspruch 1, **dadurch gekennzeichnet, dass** die Steuerelektronik (7) Informationen über den Betrieb der Lichtquelle speichern kann und die Informationen analysieren kann, um den Energieverbrauch zu minimieren.
4. Rohrförmige LED-Lichtquelle nach Anspruch 1, **dadurch gekennzeichnet, dass** die Steuerelektronik (7) mit anderen Lichtquellen oder einer zentralen Steuereinheit über das existierende installierte elektrische Stromkabel kommunizieren kann.
5. Rohrförmige LED-Lichtquelle nach Anspruch 1, **da-**

**durch gekennzeichnet, dass** sie einen oder mehrere eingebettete Sensoren (12) aufweist, um das Spektrum des Lichts der Umgebung zu messen.

6. Rohrförmige LED-Lichtquelle nach Anspruch 1, **da-  
durch gekennzeichnet, dass** sie einen oder mehrere eingebettete Sensoren (13) aufweist, um Bewegungen in der Umgebung der Lichtquelle zu messen. 5
7. Rohrförmige LED-Lichtquelle nach Anspruch 1, **da-  
durch gekennzeichnet, dass** auf der Außenfläche der Röhre (1) eine oder mehrere organische Leuchtdioden (OLED) (24) befestigt sind. 10
8. Rohrförmige LED-Lichtquelle nach Anspruch 1, **da-  
durch gekennzeichnet, dass** die Farbkomponenten im emittierten Licht individuell einstellbar sind. 15
9. Rohrförmige LED-Lichtquelle nach Anspruch 8, **da-  
durch gekennzeichnet, dass** die Farbkomponenten rot, grün und blau sind. 20
10. Rohrförmige LED-Lichtquelle nach Anspruch 1, **da-  
durch gekennzeichnet, dass** die Beleuchtungsfläche der Lichtquelle durch An-/Ausschalten oder Abblenden von einigen der LEDs (2) eingestellt werden kann. 25
11. Rohrförmige LED-Lichtquelle nach einem der Ansprüche 1-10, wobei die Röhre eine extrudierte Aluminiumröhre ist. 30

## Revendications

1. Source lumineuse à diode électroluminescente (DEL) tubulaire, comprenant : 35
  - un tube (1) fabriqué dans un matériau thermoconducteur et présentant une surface intérieure et une surface extérieure, le tube (1) étant en contact direct avec l'air ambiant de la source lumineuse ; et 40
  - une pluralité de DEL (2) montées et réparties de façon homogène sur une partie de la surface extérieure du tube (1) ; 45
  - caractérisée par**
  - une électronique de commande (7) disposée à l'intérieur du tube (1) et reliée électriquement aux DEL (2) ; 50
  - des connecteurs (10) situés à des extrémités opposées de la source lumineuse, les connecteurs étant dimensionnés pour s'ajuster dans des douilles pour tubes fluorescents, et les connecteurs (10) étant électriquement reliés à l'électronique de commande (7) ; et 55
  - dans laquelle, sur la moitié d'un côté de la zone de surface extérieure du tube (1), le tube con-

siste en une pluralité d'ailettes de refroidissement (6).

2. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce qu'il** est prévu un vide (20) à l'intérieur du tube (1).
3. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce que** l'électronique de commande (7) peut stocker des informations concernant le fonctionnement de la source lumineuse, et analyser les informations pour réduire la consommation d'énergie.
4. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce que** l'électronique de commande (7) peut communiquer par le biais d'un câble électrique déjà installé avec d'autres sources lumineuses ou avec une unité de commande centrale.
5. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce qu'elle** comporte un ou plusieurs capteurs (12) intégrés pour mesurer le spectre de la lumière depuis l'environnement.
6. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce qu'elle** comporte un ou plusieurs capteurs (13) intégrés pour mesurer des mouvements dans l'environnement de la source lumineuse.
7. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce qu'une** ou plusieurs diodes électroluminescentes organiques (OLED) (24) sont montées sur la surface extérieure du tube (1).
8. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce que** les composants de couleur dans la lumière émise peuvent être réglés individuellement.
9. Source lumineuse à DEL tubulaire selon la revendication 8, **caractérisée en ce que** les composants de couleur sont le rouge, le vert et le bleu.
10. Source lumineuse à DEL tubulaire selon la revendication 1, **caractérisée en ce que** la zone d'illumination de la source lumineuse peut être réglée en allumant/éteignant ou en assombrissant certaines des DEL (2).
11. Source lumineuse à DEL tubulaire selon l'une quelconque des revendications 1 à 10, dans laquelle le tube est un tube en aluminium extrudé.

Fig. 1

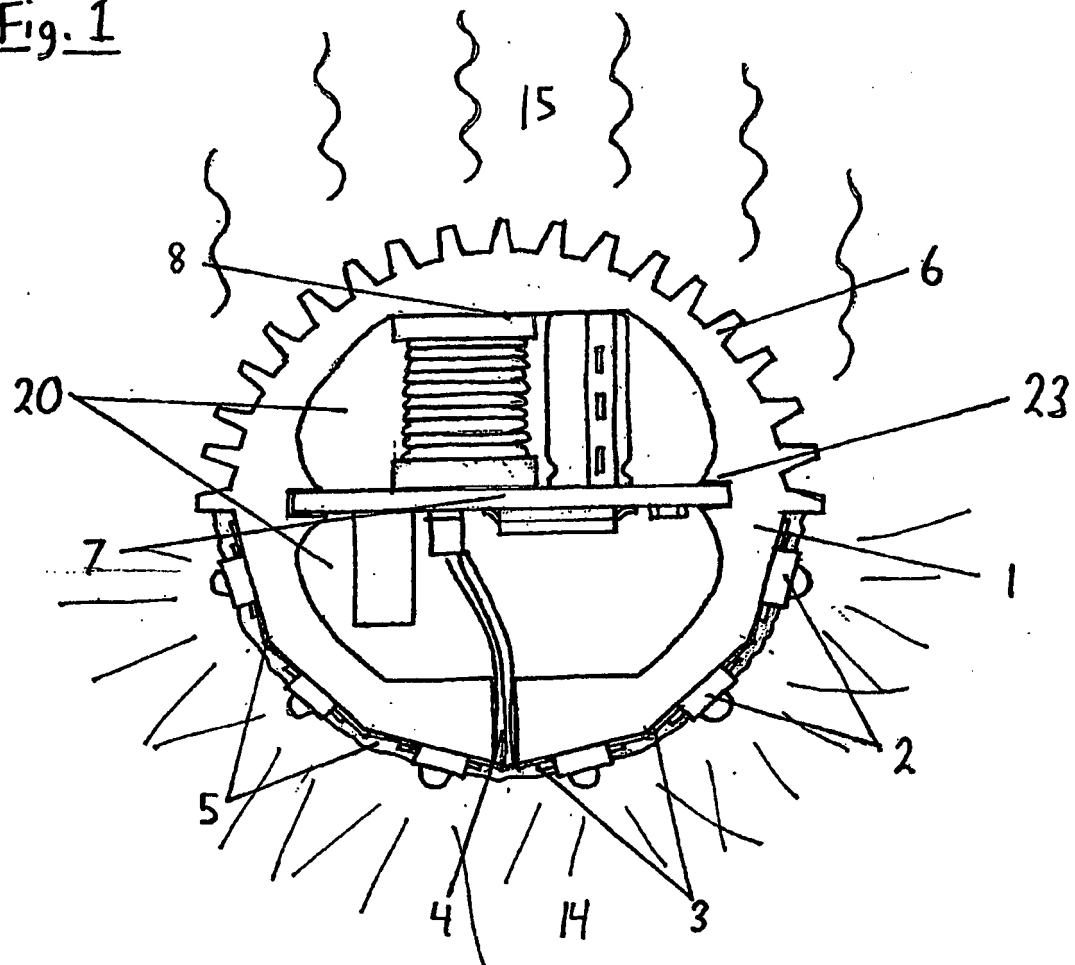


Fig. 2

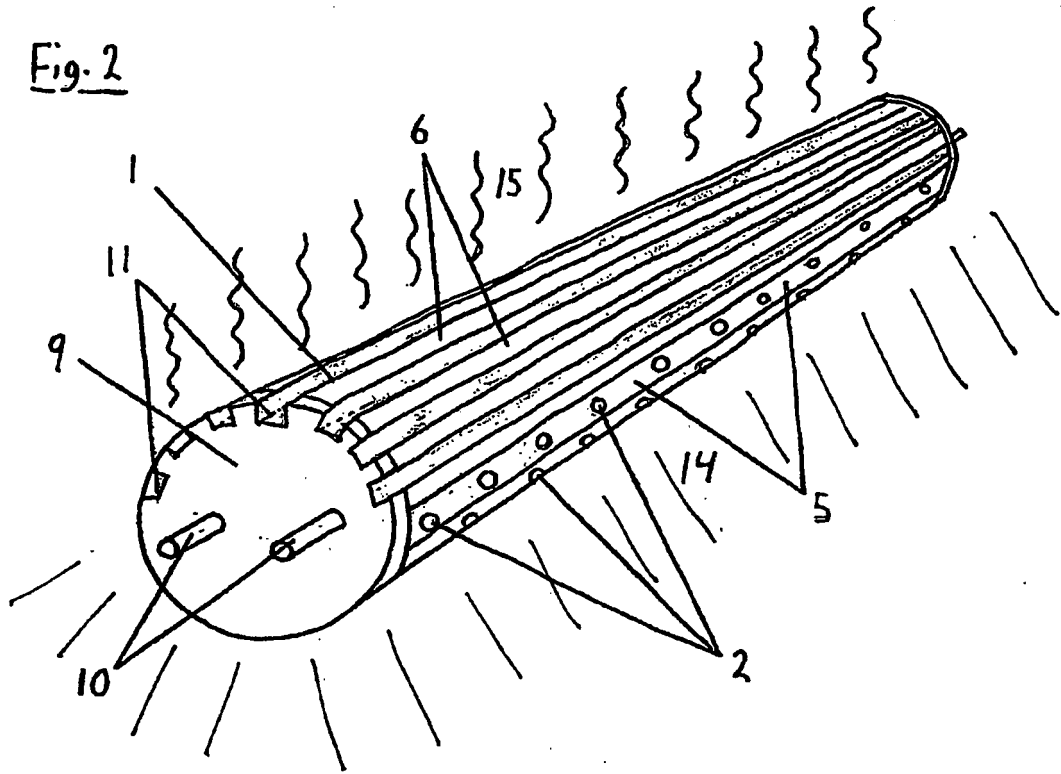


Fig. 3

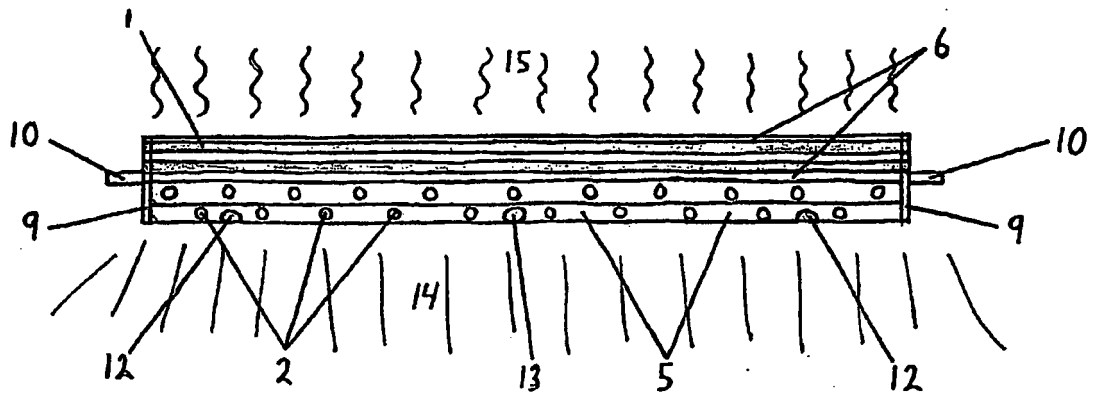
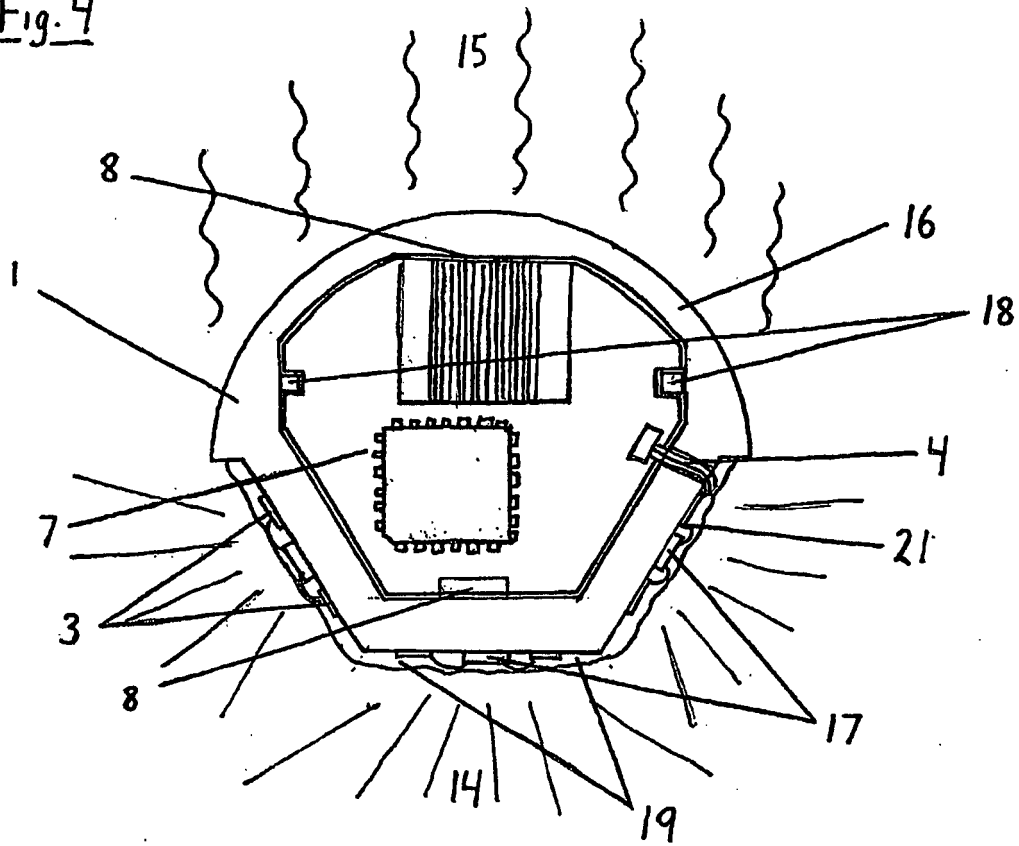
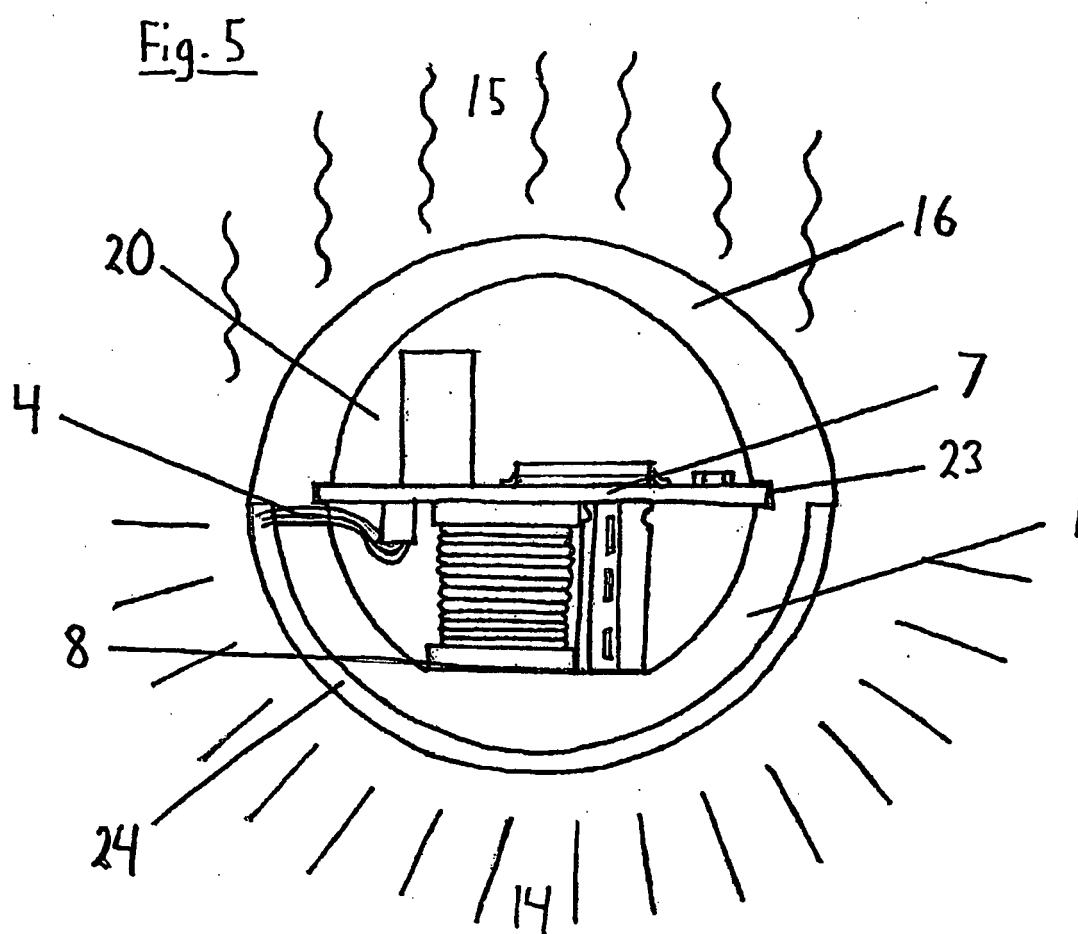




Fig. 4





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